

Peripheral Display of Digital Handwritten Notes

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ABSTRACT

We present a system for the peripheral display of digital handwritten notes, motivated by the joint observation that people seldom refer back to their notes and that these notes often contain useful information. We describe the user-led design of the system, incorporating interviews, paper prototypes, and interactive prototypes. A preliminary field trial of the system indicates that users derive value from the system both for low-distraction reminding and for serendipitous idea generation. These promising initial results suggest significant scope for future work.

Author Keywords

Peripheral display; ambient display; handwritten notes; digital ink; Tablet PC; reminders

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Note-taking is a common practice in everyday life. The circumstances under which people take notes are numerous and the range of information recorded is vast. Often there are important action items or interesting and beneficial information recorded that the note-taker intends to revisit later.

Unfortunately, the human memory is not perfect. People forget what they have recorded and sometimes they even forget that they have made a record at all. Exacerbating this problem, people do not review their records often. Previous research indicates that people rarely refer back to their notes [8, 9].

This suggests that there may be a substantial amount of latent value in peoples' notes. The problem we want to address is how to unlock that value. This is not a simple problem because that latent value is usually not clearly defined, and inappropriate presentation of recorded information could lead to unwanted interruptions, reduced productivity or frustration.

At one extreme, there is the idea of a perfect context-aware system where the most relevant and beneficial recorded information is pushed to the user at just the right time. A

simpler idea is to display the recorded information ambiently, so that even if displayed information is irrelevant to the user, it will incur minimal extra cost to them as they continue on with other tasks. These two solutions both have their own merits. However, we have chosen to start with the latter, using only very basic analysis of the notes to prioritize potentially important information. Studying this simpler approach is interesting in itself, and it may suggest achievable elements of the context-aware approach for future study.

To test this idea, we decided to focus initially on digital handwritten notes such as those taken on a Tablet PC. This decision is partly based on the increasing take-up of such devices and the expectation that it will continue to grow. More importantly, digital notes are amenable to manipulation in ways that paper notes are not. They can be copied, parsed, analyzed, segmented, rearranged and rendered in a variety of forms, all without any additional effort on the part of the user. Although paper notes could be processed in similar ways (for example via scanning and OCR) there would be substantial overhead for the user and the results would likely be inferior. We chose to focus on handwritten notes because they are more personal than typewritten documents and are also visually richer, with colors, strokes, and hand-drawn diagrams that can all serve as triggers for recall.

We, therefore, built a peripheral display that presents different parts of the user's handwritten digital notes, using fade-in/fade-out transitions. The peripheral display runs on an LCD screen in portrait mode which is placed in the periphery of the user's primary display. We gave the peripheral display to four users and collected quantitative and qualitative results after their usage. The contribution of this work lies primarily in the design of the peripheral display and the evaluation of its use to extract latent value from (digital) handwritten notes.

This paper begins with related work, covering literature on personal information management, note-taking and peripheral displays. The next section discusses design iterations, from interviews to paper and interactive prototypes. This is followed by a description of the deployed system. Then we present our field deployment and usage, and a discussion of the results. Finally, we reiterate our key findings and discuss future work.

RELATED WORK

There are three general areas of research related to the present work: personal information management (PIM), note-taking, and peripheral displays.

Personal Information Management

Previous research in PIM indicates that one of the most important functions of information management is reminding,

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and that paper has been quite a useful medium for it [3,9]. Similar reminding strategies have been adapted to digital files, [1] but as indicated by [14], digital documents lack certain affordances of paper, such as the ability to “remind through physical presence.”

Other research in PIM looks at people’s usage of technologies to facilitate the remembrance of personal information. Some look at how people use email to support the reminding function [2,15]; others try to support retrieval and re-use of encountered information [4,5]. However, as far as we are aware, no research has been conducted concerning the ambient presentation of personally authored information for reminding.

Note-Taking

Research by Hartley & Davies [6] indicates that note-taking serves two purposes. First, the process of note-taking facilitates encoding, of which there are three competing theories: *attention theory*, *effort theory*, and *generative theory* [13]. The other purpose of note-taking is the creation of external storage for information. It is not clear which purpose is more important for the recall of information, nor which of the encoding theories is more accurate, but nonetheless, seeing the content of a note can be useful and can facilitate recall of information [7, 8]. This implies a degree of latent value in unreviewed notes.

Peripheral Displays

Since our display is meant for individual use, we focus this section on personal peripheral displays. There has been previous work on peripheral displays that support multitasking and background awareness [11]. Whereas that work focused on using context information to provide peripheral awareness of related or recent tasks, our work focuses primarily on using peripheral displays to remind people of recorded information. Furthermore, our work allows the display of arbitrary recorded material, whether or not it has been recently accessed.

ITERATIVE DESIGN

To design the system, we began by interviewing both paper and tablet PC-type note takers to gain a better understanding of note-taking. We then evaluated possible design ideas using both paper and interactive prototypes.

Interview

A total of 10 people were surveyed regarding their notes and note-taking behaviors. They were all full-time researchers but with varying levels of administrative duties. Four of them did not take notes with a tablet PC, while the six that did take notes with their tablets took digital handwritten notes with varied frequency. The interviewees were asked a series of questions that were similar to those asked in [8] but with a few additional questions specific to tablet note-taking.

We found similar results to those reported by Khan for both paper and tablet note-takers. First and most importantly, our interviewees did not review their notes often. They would occasionally review notes that they took recently, but rarely would they revisit notes that had been stored for a long time. Second, our interviewees marked and highlighted their notes. Asterisks were the most common mark for importance. Highlighting, underlining, boxes, and arrows were also used.

We also found that tablet note-taking differed from paper in that because of the higher startup cost (waking up the tablet or starting the note-taking application), it was usually more of a pre-meditated act most often used for scheduled meetings or talks. It was occasionally used for a personal to-do list, and it was rarely used as a light-weight impromptu note taking medium, as one would with a post-it note. This suggests that tablet note-takers did not work in a fully paperless fashion but instead use a combination of paper and digital notes.

Paper & Interactive Prototyping

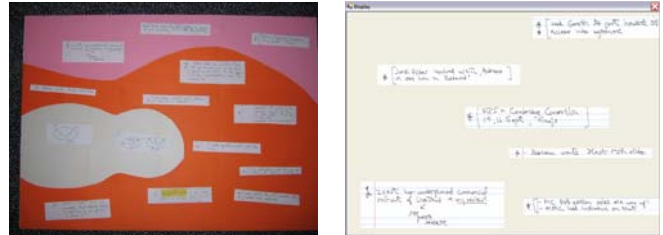


Fig. 1a. Paper Prototype

Fig. 1b. Interactive Prototype

Following our interviews, we proceeded to build paper prototypes (Fig. 1a). We printed out several tablet notes from a potential user, and cut out sections with asterisks and highlights (sections we thought best represented the important areas of the notes). We compared various note lengths and various sizes of the extracted sections to see how they appeared on the “screens.” We considered the tradeoff between visual persistence and exposure to different notes. We also considered how to design the background and layout; we wanted to use colors, shapes and spatial arrangements so that while only parts of the note are displayed, context (such as when the note was taken, where it was taken, or how it related to other notes) could be retained. However, we discovered that small note fragments were meaningful to users even without the multicolored background (in Fig. 1a), especially given a simple contextual annotation, such as the title and date of the note. Therefore, we dropped the idea of using a colorful, yet potentially distracting background.

Paper prototyping thus worked well in providing feedback regarding what to display and the display’s basic layout. However, paper prototypes cannot provide feedback regarding the tradeoff of awareness and distraction between peripheral and focal displays. Therefore, after two paper prototypes, we started implementing interactive prototypes.

For the interactive prototypes, we converted the digital ink file segments into images, and rendered those images with a C# program (*i.e.* Fig. 1b). The interactive prototypes allowed us to discover a different set of problems by enabling the displays to be used in a truly interactive setting, where the users had focal and peripheral tasks.

First, we realized there needed to be a way for the user to pin the note fragment onto the display. Otherwise, it might move or fade away, preventing the user from reading it. We also found that users wanted to adjust how fast the notes were fading, and the magnification at which they appeared. From having potential users experimenting with the display, we also found that the white background in our first prototype was too bright and distracting. Hence, we moved to a dark background.

DESCRIPTION OF SYSTEM



Fig. 2. Deployed version of the display

Basing our design on the prototype evaluations, we built the deployed system (Fig. 2) using C#, the Microsoft Tablet PC SDK 1.7, and Microsoft Journal Reader SDK 1.7. The system converts all of the user's digital ink notes into XML, parses them into asterisk-marked, highlighted and unannotated fragments, and renders the resulting InkObjects onto the screen according to a simple algorithm. The program regularly checks to see if the notes are modified, or if new ones have been added, and updates the candidate fragments accordingly.

At different times, depending on the user-selected speed, the program selects another note fragment to be displayed. Special fragments (those asterisked and highlighted) are favored over others, as with recent notes over older notes; however, all fragments have a non-zero chance of appearing.

Once a fragment is selected, it fades onto the screen. We chose fading as the transition animation because it allows note parts to be placed anywhere on the screen without following a pre-set path, and also because previous work [12] has shown that fading is one of the least distractive animations. The maximum fragment size and the magnification factor are both user-adjustable with sliders at the bottom of the screen.

We also implemented other controls. First, users can click on a fragment to highlight and pin it, where it remains until the user clicks on it again. Users can also double click on a fragment, which opens up the entire corresponding note using Windows Journal Reader on their primary display.

To facilitate the glancability of the display, and to anchor the fragments in context, we display the title and date of the note above each fragment. The titles are colored red (asterisked), yellow (highlighted) or blue (other). Below each displayed fragment, there is a 1-pixel-deep dark gray line indicating the amount of time the note has left on the display. When the line shrinks to nothing, the note begins fading off of the display.

FIELD USAGE

To gain an understanding of how the display would be used in a real-world setting, we set up the display in four researchers' offices. Three of them were given a separate 21-inch LCD, and for technical reasons, the fourth user was asked to use his second monitor as the peripheral display. Except for the fourth user, who used his existing setup, the LCDs were placed to the side of the user, about 60 degrees from the focal view.

We collected data on system use, and conducted interviews with the users at the end of the usage period. Due to the different schedules of the researchers, the length of use varied from four working days to ten working days. The number of different notes transitioned on each display also varied, ranging from 11 to 100 notes.

RESULTS

In general, the users all enjoyed using the display. They all agreed that their awareness of their notes was increased. The titles of the notes along with certain fragments, especially diagrams, were extremely helpful for remembering the note. When asked about whether or not the display was distracting, only one user thought it was slightly distracting, but added that he could easily get used to it. There were, however, reports of frustration when the users would see the same fragment frequently. Not surprisingly, this was especially a problem for the users with fewer notes for display.

The amount of direct user interaction with the display was minimal. Rarely would a user open up notes through the display, on average, less than once daily. Users used the pinning function even less. The only control that the users interacted with was the slider for the size of the fragments.

Infrequent direct interaction did not mean the display was not useful; in fact, all of our participants thought the display was valuable. When we probed further to understand how it was useful, there were two types of value that this display provided to the user. First, it reminded users of valuable information that they had forgotten. One user said

when I moved office...I scribbled down what was on my whiteboard, and I'd completely forgotten that I'd done that...I suddenly saw something [on the peripheral display] which was very useful to have noticed it

Another talked about how he would find himself re-writing something that he had already started previously. Seeing the note on the display saved him from wasting time on something he had already done. Second, the display was also valuable in that it facilitated thinking and brainstorming. One user said

[when] you get stuck [while writing], you kind of glance around the room, and usually this isn't very productive, but [looking at the display], ahh that's exactly what am I'm going to say here

Another user talked about how he had been thinking about a problem for a week. Seeing a note fragment from a previous lecture sparked a potential solution that he planned to try out.

We also asked how users felt and dealt with the issue of privacy. Most thought it wasn't a significant problem, but more than one did hope that in future versions there would be means to mark notes or fragments as "not to be displayed" either during the note-taking process, or when they appeared on the peripheral display.

DISCUSSION

The biggest problem reported by users of the current design is the occasional frustration felt when seeing the same fragment too often. Of course, this is largely the result of having a relatively small set of notes. A pilot user (not one of the 4 in the field study) who had several hundred notes did not experience this problem. We could address this problem by expanding the types of recorded information being displayed. Some users requested that we allow PDF and text files to be shown on the display, and one could imagine adding other document types. However, this would move us beyond the idea of rendering strictly self-authored material and there is still much to be explored in that space.

We noticed during the field study that two of the users would often run other applications on top of ours and move the second monitor closer to their primary monitor. That allowed them to use the extra LCD as a monitor with our peripheral display in the background. There are two possible explanations for this behavior. One is that the display functioned well as a background display; people were getting value out of it even though parts of the display were occluded, and they were not being distracted by the display being directly in the background. The other possible explanation is that since users' display space is limited, they wanted to place the most relevant and useful information on the display. They were willing to exchange information regarding their notes for information more closely associated with their current tasks. This is not to say that the information in the notes was not useful. It just indicates that people cannot accurately forecast the benefit of seeing their notes, which partly explains why people do not review their notes in the first place. The user who was reminded of the forgotten to-do item questioned the benefits of using the display at first, but because the display reminded him of that one important task, changed his mind.

Hence, one lesson learned is that when minimizing cost for a display like this, we have to consider both interruption cost and screen real estate cost. Improvements can be made by exploiting available and unused display space. One user said during the interview that he probably would not pay the cost of a separate LCD to support our display, but he would definitely use something like this if it were a wallpaper or screensaver. Additionally, using the tablet PC's screen as the display while the user is engaged with their desktop in the office would allow the user to have the peripheral display without sacrificing display space. This latter approach would facilitate a much broader field study with dozens or even hundreds of participants, and is something we intend to pursue.

CONCLUSION & FUTURE WORK

Although the field study provided mostly anecdotal evidence, from the positive feedback we received, it is clear that there are benefits in using this display as a low-distraction reminder, and to facilitate the serendipitous generation of ideas. During the design phase, we gained a better understanding of how paper and interactive prototyping differed in function for peripheral displays, and the importance of designing to minimize interruption and screen real estate cost.

The most pressing next step is to run a much more extensive field trial where we can verify our preliminary findings and

elucidate new ones. As discussed, we intend to do this by means of the wallpaper/screensaver version running on the user's idle docked tablet PC. Future work includes looking at ways to improve the selection process, so that more value can be associated with seeing a note fragment. This may include exploring ways to make the display more context-aware, so that task-related fragments would appear at more opportune times while keeping the amount of distraction low and still allowing the opportunity for serendipitous value at other times.

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REFERENCES

1. Barreau, D., Nardi, B. A. Finding and Reminding, File Organization from the Desktop. *SIGCHI Bulletin*, **27**(3), July '95, pp. 39-43.
2. Bellotti, V. & Smith, I. Informing the Design of an Information Management System with Iterative Fieldwork. *Proc. DIS '00*, pp. 227-237.
3. Campbell, C.S., Maglio, P. P. Supporting Notable Information in Office Work. *Proc. CHI '03*, pp. 902-903.
4. Dumais, S., Cutrell, E., Cadiz, JJ, Jancke, G., Raman, S., Robbins, D. C. Stuff I've Seen: A System for Personal Information Retrieval and Re-Use. *Proc. SIGIR '03*.
5. Flynn M. & Lamming, M. "Forget-me-not" Intimate Computing in Support of Human Memory. *Proc. FRIEND21 '94*.
6. Hartley, J. & Davies, I.K. Note-taking: A critical review. In *Journal of Educational Psychology*, **67**, pp. 291-292.
7. Hartley, J. Note-taking research: Resetting the scoreboard. In *Bulletin of the British Psychological Society*, **36**, pp. 13-14.
8. Khan, F. A Survey of Note-Taking Practices. HPL-93-107.
9. Kidd, A. The Marks are on the Knowledge Worker. *Proc. CHI '94*, pp 186-191.
10. Malone, T. W. How Do People Organize Their Desks? Implications for the Design of Office Information Systems. *ACM Transactions on Office Information Systems*, **1**(1), January 1983, pp. 99-112.
11. MacIntyre, B., Mynatt, E. D., Vaida, S., Hansen, K.M., Tullio, J., Corso, G. M. Support For Multitasking and Background Awareness Using Interactive Peripheral Displays. *Proc. UIST '01*, pp. 41-50.
12. McCrickard, D. S., Catrambone, R., Chewar, C. M., Stasko, J. T. "Establishing Tradeoffs that Leverage Attention for Utility: Empirically Evaluating Information Display in Notification Systems." *IJHCS*, **8**(5), May 2003, pp. 547-582.
13. Peper, R. J. and Mayer, R. E. Note Taking as a Generative Activity. *Journal of Education Psychology* 1978, **70**(4).
14. Sellen, A. B., Harper, R. H. R. *The Myth of the Paperless Office*, MIT Press, Cambridge, MA, 2003.
15. Whittaker, S. & Sidner, C. Email Overload: Exploring Personal Information Management of Email. *Proc. CHI '96*. pp. 276-283.